

1.1 Background

A major goal of the Oil Pollution Act of 1990 (OPA)¹ is to make the environment and public whole for injury to or loss of natural resources and services as a result of a discharge or substantial threat of a discharge of oil (referred to as an *incident*). This goal is achieved through returning injured natural resources and services to the condition they would have been in if the incident had not occurred (otherwise referred to as *baseline* conditions), and compensating for interim losses from the date of the incident until recovery of such natural resources and services through the restoration, rehabilitation, replacement, or acquisition of equivalent natural resources and/or services.

The U.S. Department of Commerce, acting through the National Oceanic and Atmospheric Administration (NOAA), issued final regulations providing an approach that public officials (trustees) may use when conducting Natural Resource Damage Assessments (NRDA) under OPA.² These NRDA regulations (the OPA regulations) describe a process by which trustees may:

- Identify injuries to natural resources and services resulting from an incident;
- Provide for the return of injured natural resources and services to baseline conditions and compensation for interim lost services; and
- Encourage and facilitate public involvement in the restoration process.

The OPA regulations are included in Appendix A of this document for reference. The preamble discussion of the OPA regulations, along with a summary of and response to public comments received on the proposed regulations, is published at 61 Fed. Reg. 440 (January 5, 1996).

¹ 33 U.S.C. §§ 2701 *et seq.*

² The OPA regulations are codified at 15 CFR part 990 and became effective February 5, 1996.

1.2 Purpose and Scope of this Document

The purpose of the Restoration Guidance Document is to review the state of the art for restoration of certain habitats and biological natural resources and evaluate potential restoration actions following injury to natural resources resulting from the discharge of oil. Trustees should refer to Appendix B for a listing of this and other related guidance documents in support of the OPA regulations.

The following tasks were conducted in developing this document:

- Identify and evaluate oil-related restoration methods/techniques that are currently available for feasibility, effectiveness and success, and costs. This evaluation is performed on each habitat and biological natural resource (species population) of concern in aquatic environments.
- Evaluate oil-related restoration actions, including development of a ranking scheme to be used in restoration decisionmaking.
- Identify and evaluate tested or promising methods/techniques for non-oil contaminant situations that provide direct insights to oil discharge-related restoration activities for feasibility, effectiveness and success, and costs. Evaluate the applicability of these methods to oil-affected habitats. Evaluate actions as in the above task. The non-oil activities review was, however, limited to approaches that provide direct insights to oil discharge-related restoration actions.

This review is extensive but certainly not exhaustive. A vast literature on restoration and mitigation exists. The authors have attempted to review only information applicable to oil discharges. Additional bibliographies exist. The Restoration Center (NMFS, NOAA, Silver Spring, MD) has developed a directory of restoration experts (Restoration Center, 1996) and maintains a computer database of references (Tim Osborn, contact). There is also a Mitigation Evaluation Data Base maintained by the U.S. Fish and Wildlife Service (USF&WS, Fort Collins, CO, Hamilton and Roelle, 1987, Roelle, 1988). There are several annotated bibliographies focusing on wetland restoration, for example by Schneller-McDonald et al. (1990, also USF&W, Fort Collins, CO). Other sources of information are cited in the following sections, including articles compiled into books and symposia volumes on restoration.

The guidance in this document is meant to summarize existing information and state of the art methods, so that informed decisions can be made in the restoration planning and implementation process. The volume of material presented on restoration reflects more the availability of information than a recommendation to pursue that action.

1.3 Intended Audience

This document was prepared primarily to provide guidance to natural resources trustees using the OPA regulations. However, other interested persons may also find the information contained in this document useful and are encouraged to use this information where appropriate.

1.4 The NRDA Process

The NRDA process shown in Exhibit 1.1 in the OPA regulations includes three phases outlined below: Preassessment; Restoration Planning; and Restoration Implementation.

1.4.1 Preassessment Phase

The purpose of the Preassessment Phase is to determine if trustees have the jurisdiction to pursue restoration under OPA, and, if so, whether it is appropriate to do so. This preliminary phase begins when the trustees are notified of the incident by response agencies or other persons.

Once notified of an incident, trustees must first determine the threshold criteria that provide their authority to initiate the NRDA process, such as applicability of OPA and potential for injury to natural resources under their trusteeship. Based on early available information, trustees make a preliminary determination whether natural resources or services have been injured. Through coordination with response agencies, trustees next determine whether response actions will eliminate the threat of ongoing injury. If injuries are expected to continue, and feasible restoration alternatives exist to address such injuries, trustees may proceed with the NRDA process.

1.4.2 Restoration Planning Phase

The purpose of the Restoration Planning Phase is to evaluate potential injuries to natural resources and services and use that information to determine the need for and scale of restoration actions. The Restoration Planning Phase provides the link between injury and restoration. The Restoration Planning Phase has two basic components: injury assessment and restoration selection.

NATURAL RESOURCE DAMAGE ASSESSMENT
Oil Pollution Act of 1990
Overview of Process

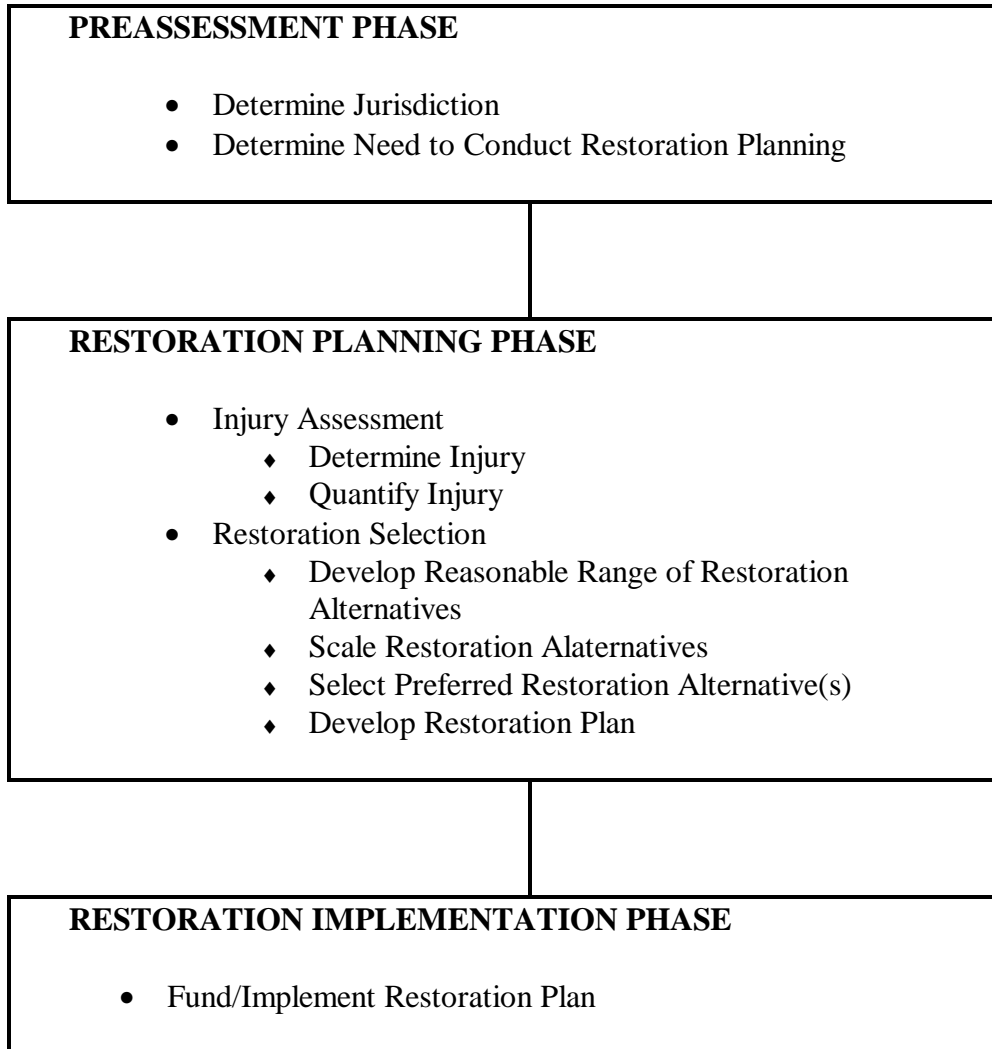


Exhibit 1.1 NRDA process under the OPA regulations.

1.4.2.1 Injury Assessment

The goal of injury assessment is to determine the nature, degree, and extent of any injuries to natural resources and services. This information is necessary to provide a technical basis for evaluating the need for, type of, and scale of restoration actions. Under the OPA regulations, injury is defined as an observable or measurable adverse change in a natural resource or impairment of a natural resource service. Trustees determine whether there is:

- Exposure, a pathway, and an adverse change to a natural resource or service as a result of an actual discharge; or
- An injury to a natural resource or impairment of a natural resource service as a result of response actions or a substantial threat of a discharge.

To proceed with restoration planning, trustees also quantify the degree, and spatial and temporal extent of injuries. Injuries are quantified by comparing the condition of the injured natural resources or services to baseline, as necessary.

1.4.2.2 Restoration Selection

(a) Developing Restoration Alternatives

Once injury assessment is complete or nearly complete, trustees develop a plan for restoring the injured natural resources and services. Under the OPA regulations, trustees must identify a reasonable range of restoration alternatives, evaluate and select the preferred alternative(s), and develop a Draft and Final Restoration Plan. Acceptable restoration actions include any of the actions authorized under OPA (restoration, rehabilitation, replacement, or acquisition of the equivalent) or some combination of those actions

Restoration actions under the OPA regulations are either primary or compensatory. Primary restoration is action taken to return injured natural resources and services to baseline, including natural recovery. Compensatory restoration is action taken to compensate for the interim losses of natural resources and/or services pending recovery. Each restoration alternative considered will contain primary and/or compensatory restoration actions that address one or more specific injuries associated with the incident. The type and scale of compensatory restoration may depend on the nature of the primary restoration action, and the level and rate of recovery of the injured natural resources and/or services given the primary restoration action.

When identifying the compensatory restoration components of the restoration alternatives, trustees must first consider compensatory restoration actions that provide services of the same type and quality, and of comparable value as those lost. If compensatory actions of the same type and quality and comparable value cannot provide a reasonable range of alternatives, trustees then consider other compensatory restoration actions that will provide services of at least comparable type and quality as those lost.

(b) Scaling Restoration Actions

To ensure that a restoration action appropriately addresses the injuries resulting from an incident, trustees must determine what scale of restoration is required to return injured natural resources to baseline levels and compensate for interim losses. The approaches that may be used to determine the appropriate scale of a restoration action are the resource-to-resource (or service-to-service approach) and the valuation approach. Under the resource-to-resource or service-to-service approach to scaling, trustees determine the appropriate quantity of replacement natural resources and/or services to compensate for the amount of injured natural resources or services.

Where trustees must consider actions that provide natural resources and/or services that are of a different type, quality, or value than the injured natural resources and/or services, or where resource-to-resource (or service-to-service) scaling is inappropriate, trustees may use the valuation approach to scaling, in which the value of services to be returned is compared to the value of services lost. Responsible parties (RPs) are liable for the cost of implementing the restoration action that would generate the equivalent value, not for the calculated interim loss in value. An exception to this principle occurs when valuation of the lost services is practicable, but valuation of the replacement natural resources and/or services cannot be performed within a reasonable time frame or at a reasonable cost. In this case, trustees may estimate the dollar value of the lost services and select the scale of the restoration action that has the cost equivalent to the lost value.

(c) Selecting a Preferred Restoration Alternative

The identified restoration alternatives are evaluated based on a number of factors that include:

- Cost to carry out the alternative;
- Extent to which each alternative is expected to meet the trustees' goals and objectives in returning the injured natural resources and services to baseline and/or compensating for interim losses;
- Likelihood of success of each alternative;

- Extent to which each alternative will prevent future injury as a result of the incident, and avoid collateral injury as a result of implementing the alternative;
- Extent to which each alternative benefits more than one natural resource and/or service; and
- Effect of each alternative on public health and safety.

Trustees must select the most cost-effective of two or more equally preferable alternatives.

(d) Developing a Restoration Plan

A Draft Restoration Plan will be made available for review and comment by the public, including, where possible, appropriate members of the scientific community. The Draft Restoration Plan will describe the trustees' preassessment activities, as well as injury assessment activities and results, evaluate restoration alternatives, and identify the preferred restoration alternative(s). After reviewing public comments on the Draft Restoration Plan, trustees develop a Final Restoration Plan. The Final Restoration Plan will become the basis of a claim for damages.

1.4.3 Restoration Implementation Phase

The Final Restoration Plan is presented to the RPs to implement or fund the trustees' costs of implementing the Plan, therefore providing the opportunity for settlement of the damage claim without litigation. Should the RPs decide to decline to settle the claim, OPA authorizes trustees to bring a civil action for damages in federal court or to seek an appropriation from the Oil Spill Liability Trust Fund (FUND) for such damages.

1.5 Basic Terms and Definitions

The term *restoration* is often confused with other similar terms, such as *mitigation*. These various terms are utilized and defined in a variety of ways by various authors. Often the uses of these terms are not very rigorous. For the purposes of the present analysis, it is important to define with some precision what is implied by the term *restoration*.

In the NEPA regulations, the Council on Environmental Quality (1981) provides a broad definition of *mitigation* (Whitaker, 1979):

Mitigation includes:

- Avoiding the impact altogether by not taking a certain action or parts of an action.
- Minimizing impacts by limiting the degree or magnitude of action and its implementation.
- Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.
- Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.
- Compensating for the impact by replacing or providing substitute resources or environments (40 CFR Part 1508.20 (a-e)).

The U.S. Fish and Wildlife Service (USFWS) has adopted the above definition of *mitigation* and considers the steps to be in order of desirability in planning (Zagata, 1985). However, in the case of an existing discharge that has caused some impact to a given habitat, *mitigation* would include actions that may be categorized under the third and fifth bullets (i.e., restoration, rehabilitation, replacement, and/or acquisition of the equivalent of lost natural resources or environments). The usage of *mitigation* as including either restoration or replacement actions is a more typical use of the term (Jaworski and Raphael, 1979; Schnick et al., 1982).

In the literature, *restoration* usually refers to actions undertaken to return injured natural resources or services to their baseline condition; that is, at the site (Schnick et al., 1982; Cairns and Buikema, 1984; Cairns, 1988a, 1988b, 1991; Helvey et al., 1991; EVOS-RPWG, 1990b). The term *baseline* is used rather than *predischage* because, absent the oil discharge, the natural resources may have changed over time creating a baseline different than the predischage condition. Getter et al. (1984) state that restoration is man's efforts to initiate and/or enhance the recovery process. However, *restoration* is used more generally to include the mitigation actions listed above as provided under the OPA regulations.

Rehabilitation refers to actions that may bring injured natural resources or services to a state different from the predischARGE condition, yet beneficial to both the environment and public. This may be necessitated by the fact that it may not be possible to return an ecosystem to the predisturbance condition. For example, species characterizing earlier states of succession may no longer be present, or exotics may be the post-disturbance colonizers (Cairns, 1989). Rehabilitation has also been termed *partial restoration* in that some previously present natural resources and/or functions are restored, while other new, but desirable, ones are introduced. Therefore, rehabilitation may be considered a mix of restoration, replacement, and natural recovery actions (Helvey et al., 1991).

Replacement refers to substituting natural resources or services for those injured. For instance, habitats away from the site of impact may be created or enhanced that provide comparable services in terms of fish and wildlife production (e.g., HEP procedures, U.S. Fish and Wildlife Service, 1980a, 1980b; Schnick et al., 1982; Larson and Neill, 1987; McCollum, 1988). Other lost services provided by natural resources that might be replaced include recreational services, water supply, absorption of nutrients and pollutants (i.e., assimilative capacity), flood and storm damage protection, erosion control, and harvest of natural products (Larson and Neill, 1987; Tiner, 1989).

Acquisition of the equivalent refers to obtaining ownership or other rights to natural resources or services that are comparable to those injured. Typically, it does not involve any direct action on the natural resources themselves, but should be preventative of future impacts, and so be of net benefit.

In the present context, restoration actions performed on-site to facilitate recovery of the affected natural resources will be referred to as *direct restoration*. *Direct habitat restoration* is performed on habitats, while *direct resource restoration* is performed on injured species populations (i.e., fish, shellfish, wildlife). In some cases, direct restoration efforts will actually result in rehabilitation, also assumed to be performed on-site. *Replacement* will refer to actions performed off-site, which serve to mitigate the impact by replacing services lost. The restoration actions described in this document all refer to *primary restoration actions* under the OPA regulations. *Mitigation* or simply *restoration* will be used in a general sense as defined under the OPA regulations.

Except in emergency situations, restoration generally is distinguished from *response* as being performed after the fact and by public trustees, while *response* includes actions performed at the time of the discharge by response agencies (Getter et al., 1984). Response includes containment, cleanup, and protection. Restoration may include physical removal of substrate and vegetation, replanting, and restocking of animal populations.

Definitions under the OPA regulations are contained in Appendix A (§ 990.30 of the OPA rule). Only the more relevant terms are defined below.

1.5.1 Baseline

Baseline means the condition of the natural resources and services that would have existed had the incident not occurred. Baseline data may be estimated using historical data, reference data, control data, or data on incremental changes (e.g., number of dead animals), alone or in combination, as appropriate.

1.5.2 Damages

Damages means damages specified in section 1002(b) of OPA (33 U.S.C. 1002(b)), and includes the costs of assessing these damages, as defined in section 1001(5) of OPA (33 U.S.C. 2701(5)).

1.5.3 Injury

Injury means an observable or measurable adverse change in a natural resource or impairment of a natural resource service. Injury may occur directly or indirectly to a natural resource and/or service. Injury incorporates the terms destruction, loss, and loss of use as provided in OPA.

1.5.4 Natural Resources

Natural resources means land, fish, wildlife, biota, air, water, ground water, drinking water supplies, and other such resources belonging to, managed by, held in trust by, appertaining to, or otherwise controlled by the United States (including the resources of the Exclusive Economic Zone), any state or local government or Indian tribe, or any foreign government, as defined in section 1001(20) of OPA (33 U.S.C. 2701(20)).

Natural resources refer to both habitats (e.g., rocky shores, mud flats, saltmarshes, etc.), and individual biological resources (i.e., animal and plant species, populations, communities, etc.).

1.5.5 Oil

Oil means oil of any kind or in any form, including, but not limited to, petroleum, fuel oil, sludge, oil refuse, and oil mixed with wastes other than dredged spoil. However, the term does not include petroleum, including crude oil or any fraction thereof, that is specifically listed or designated as a hazardous substance under 42 U.S.C. 9601(14)(A) through (F), as defined in section 1001(23) of OPA (33 U.S.C. 2701(23)).

1.5.6 Recovery

Recovery means the return of injured natural resources and services to baseline.

1.5.7 Response

Response (or remove or removal) means containment and removal of oil or a hazardous substance from water and shorelines or the taking of other actions as may be necessary to minimize or mitigate damage to the public health or welfare, including, but not limited to, fish, shellfish, wildlife, and public and private property, shorelines, and beaches, as defined in section 1001(30) of OPA (33 U.S.C. 2701(30)).

1.5.8 Restoration

Restoration means any action (or alternative), or combination of actions (or alternatives), to restore, rehabilitate, replace, or acquire the equivalent of injured natural resources and services. Restoration includes: (a) Primary restoration, which is any action, including natural recovery, that returns injured natural resources and services to baseline; and (b) Compensatory restoration, which is any action taken to compensate for interim losses of natural resources and services that occur from the date of the incident until recovery.

The OPA regulations also include the concepts of primary and compensatory restoration. Primary restoration is any action that returns injured resources and services to baseline conditions, including natural recovery. Natural recovery refers to the taking of no human intervention to directly restore the injured natural resources and services. Depending on the injury of concern, primary restoration actions may include actions to actively accelerate recovery or simply to remove conditions that would make recovery unlikely. For each injury (or loss), trustees must consider compensatory restoration actions to compensate for the interim loss of natural resources and services pending recovery.

1.6 Natural Resources Evaluated

The habitats evaluated in this document are estuarine/marine (saltwater) and freshwater habitats. Exhibit 1.2 lists the habitat categories considered for the evaluation of restoration alternatives and actions within this document.

Exhibit 1.2 is a simplification of the detailed classification system in Cowardin et al. (1979). Cowardin et al. define five major systems: marine, estuarine, riverine, lacustrine and palustrine. The marine and estuarine systems include all waters >0.5‰ salinity (i.e., brackish and saltwater habitats). Riverine, lacustrine, and palustrine are freshwater (<0.5‰) habitats. Riverine habitats are contained within a channel characterized by a flow, either tidally- or gradient-driven. Cowardin et al. (1979) categorize gradient-driven riverine as upper perennial (e.g., brook), lower perennial (e.g., river on a plain), or intermittent. Lacustrine habitats are those situated in a topographic depression or dammed river channel, having less than 30% areal coverage of vegetation, and greater than 8 ha in area (i.e., lakes and ponds). Palustrine habitats are non-tidal freshwater (<0.5‰) wetlands.

Wetland types include emergent, shrub-scrub, forested, aquatic bed, and bog and fens. Emergent wetlands (i.e., marshes) are characterized by erect, rooted, herbaceous perennials. In the marine and estuarine systems, emergent wetlands are the (intertidal) saltmarshes, typically dominated by *Spartina* spp. or *Salicornia* spp. In freshwater systems (riverine, lacustrine and palustrine), marshes contain a diverse assemblage of species (e.g., cattails, rushes, bulrushes, sedges). Shrub/scrub wetlands are freshwater and dominated by woody vegetation less than 6 m tall. Forested wetlands (i.e., swamps) are dominated by woody vegetation greater than 6 m tall. In the marine and estuarine systems, these are mangrove swamps. In freshwater systems, these are hardwood or softwood (coniferous) swamps. Aquatic beds are freshwater wetlands or deepwater habitats dominated by submerged or floating vegetation (e.g., naiads, water lilies). These would be referred to as *weedy shallows* in common parlance. Bogs and fens are dominated by mosses and lichens, and are typically arctic, subarctic, and alpine habitats.

1.7 Possible Restoration Alternatives and Actions

Exhibit 1.3 outlines possible restoration actions under various alternatives, which may be included in a restoration program. Specific actions by habitats and natural resources are provided in Exhibit 1.4. These actions are analyzed in this document. While some of these actions are also used in response, it may be necessary to employ them in the restoration context as well. Therefore, the context under which these actions are reviewed is for restoration, not response. The term *cleanup* is often used as a response action. However, some *cleanup* activities might be correctly considered part of restoration. For this reason, the term *cleanup* will be used in reviewing documentation of response actions, with the understanding that in some situations cleanup techniques are the first step in the restoration process.

The listed actions in Exhibit 1.4 include those with some level of technical feasibility and chance of effectiveness. Those with no viability are not listed, evaluations of feasibility and cost are not provided. However, the reasons for their lack of effectiveness are included in Chapter 3. Inclusion in Exhibits 1.3 or 1.4 does not indicate that the action is recommended in all or any situations. The list is simply to provide organization of the evaluation and discussion.

Exhibit 1.2 Habitat categories considered in restoration guidance.

- I. Estuarine and Marine (Saltwater)
 - A. Intertidal
 - 1. Rocky shore
 - 2. Cobble-gravel beach
 - 3. Sand beach
 - 4. Mud flat
 - 5. Saltmarsh
 - 6. Mangrove swamp
 - 7. Macroalgal bed.
 - 8. Mollusk reef
 - 9. Coral reef
 - 10. Seagrass Bed
 - B. Subtidal
 - 1. Rock Bottom
 - 2. Cobble-gravel bottom
 - 3. Sand bottom
 - 4. Silt-mud bottom
 - 5. Macroalgal (kelp) bed
 - 6. Mollusk reef
 - 7. Coral reef
 - 8. Seagrass bed
- II. Riverine
 - A. Vegetated (Wetlands)
 - 1. Emergent wetland (marsh)
 - 2. Shrub/scrub wetland
 - 3. Forested wetland (swamp)
 - 4. Aquatic bed
 - B. Non-vegetated
 - 1. Rock bottom
 - 2. Cobble-gravel bottom
 - 3. Sand bottom
 - 4. Silt-mud bottom
 - C. Shoreline
 - 1. Rock shore
 - 2. Cobble-gravel shore
 - 3. Sand shore
 - 4. Mud shore
- III. Lacustrine
 - A. Submerged
 - 1. Rock bottom
 - 2. Cobble-gravel bottom
 - 3. Sand bottom
 - 4. Silt-mud bottom
 - B. Shoreline
 - 1. Rocky shore
 - 2. Cobble-gravel shore
 - 3. Sand shore
 - 4. Mud shore
- IV. Palustrine (Wetlands)
 - A. Aquatic bed (submerged vegetation)
 - B. Emergent wetland (marsh)
 - C. Shrub/scrub wetland
 - D. Forested wetland (swamp)
 - E. Bogs and fens

Exhibit 1.3 Restoration actions for each alternative.

1. Natural Recovery - Monitoring
2. Direct Restoration
 - a. Direct Habitat Restoration
 - Contaminant Removal
 - Reconstruction
 - Replanting
 - Accelerated Degradation
 - Monitoring
 - Maintenance
 - b. Direct Resource Restoration
 - Restocking
 - Harvest Alteration
 - Enhancement
 - Monitoring
 - Maintenance
3. Rehabilitation
 - a. Habitats
 - Contaminant Removal
 - Reconstruction
 - Replanting
 - Accelerated Degradation
 - Monitoring
 - Maintenance
 - b. Resources
 - Stocking
 - Harvest Alteration
 - Enhancement
 - Monitoring
 - Maintenance
4. Replacement
 - a. Habitats
 - Enhancement
 - Creation
 - Monitoring
 - Maintenance
 - b. Resources
 - Reconstruction
 - Replanting
 - Accelerated Degradation
 - Monitoring
 - Maintenance
 - c. Non-biological Services
 - Recreational
 - Commercial
 - Cultural
5. Acquisition of Equivalent Resources
 - Acquire Property Rights
 - Protection or Management
6. Combination of the Above

Exhibit 1.4 Possible restoration actions that are evaluated for each habitat and biological natural resource.

I. HABITATS

SALTMARSH

- Natural recovery monitoring
- Low pressure flushing
- Vegetative cropping
- Sediment removal and replacement
- Replanting
- Supplementary erosion control structures
- Bioremediation:
 - Fertilizer application
 - Oleophilic agents
 - Microbial seeding
 - Tilling of surface sediments
- Wetland enhancement
- Saltmarsh creation

MANGROVE SWAMP

- Natural recovery monitoring
- Low pressure flushing
- Opening of channels
- Replanting (various methods)
- Bioremediation:
 - Fertilizer application
 - Oleophilic agents
 - Microbial seeding
 - Tilling of surface sediments
- Enhancement
- Creation

FRESHWATER WETLANDS

- Natural recovery monitoring
- Low pressure flushing
- Vegetative cropping
- Sediment removal and replacement
- Replanting
- Supplementary erosion control structures
- Bioremediation:
 - Fertilizer application
 - Oleophilic agents
 - Microbial seeding
 - Tilling of surface sediments
- Wetland enhancement

Exhibit 1.4 (continued)

BOGS AND FENS

Natural recovery monitoring

Bioremediation:

Fertilizer application

Oleophilic agents

Microbial seeding

INTERTIDAL MACROALGAL BED

Natural recovery monitoring

Vegetative cropping

Replanting

SUBTIDAL MACROALGAL (KELP) BED

Natural recovery monitoring

Vegetative cropping

Replanting

Herbivore control

Kelp bed enhancement (off-site)

Kelp bed creation

SEAGRASS BED

Natural recovery monitoring

Replanting

Herbivore control

Seagrass bed enhancement (off-site)

Reconstruction

Coral transplants

MARINE AND ESTUARINE ROCKY SHORE

Natural recovery monitoring

Flushing (pressure and temperature variable)

Flushing with chemical remediation

Sand blasting

Steam cleaning

Bioremediation:

Fertilizer application

Oleophilic agents

Microbial seeding

Exhibit 1.4 (continued)

MARINE AND ESTUARINE SAND BEACH

- Natural recovery monitoring
- Flushing (pressure and temperature variable)
- Sediment washing
- Agitation
- Sediment removal and replacement
- Bioremediation:
 - Fertilizer application
 - Oleophilic agents
 - Microbial seeding
 - Tilling of surface sediments (agitation)
- Incineration

MARINE AND ESTUARINE INTERTIDAL MUD FLAT

- Natural recovery monitoring
- Sediment removal and replacement
- Bioremediation:
 - Fertilizer application
 - Oleophilic agents
 - Microbial seeding
 - Tilling of surface sediments (agitation)

MARINE AND ESTUARINE SUBTIDAL ROCK BOTTOM

- Natural recovery monitoring

MARINE AND ESTUARINE SUBTIDAL COBBLE-GRAVEL BOTTOM

- Natural recovery monitoring
- Dredging
- Sediment replacement

MARINE AND ESTUARINE SUBTIDAL SAND BOTTOM

- Natural recovery monitoring
- Dredging
- Sediment replacement
- Capping

MARINE AND ESTUARINE SUBTIDAL SILT-MUD BOTTOM

- Natural recovery monitoring
- Dredging
- Sediment replacement
- Capping

Exhibit 1.4 (continued)

RIVERINE ROCKY SHORE

- Natural recovery monitoring
- Sand blasting
- Steam cleaning
- Flushing (pressure and temperature variables)
- Flushing with chemical remediation
- Bioremediation:
 - Fertilizer application
 - Oleophilic agents
 - Microbial seeding

RIVERINE COBBLE-GRAVEL SHORE

- Natural recovery monitoring
- Flushing (pressure and temperature variables)
- Flushing with chemical remediation
- Sediment washing
- Agitation
- Bioremediation:
 - Fertilizer application
 - Oleophilic agents
 - Microbial seeding
 - Tilling of surface sediments (agitation)

RIVERINE SAND SHORE

- Natural recovery monitoring
- Flushing (pressure and temperature variables)
- Sediment washing
- Agitation
- Sediment removal and replacement
- Bioremediation:
 - Fertilizer application
 - Oleophilic agents
 - Microbial seeding
 - Tilling of surface sediments (agitation)
- Incineration

RIVERINE SILT-MUD SHORE

- Natural recovery monitoring
- Sediment removal and replacement
- Bioremediation:
 - Fertilizer application
 - Oleophilic agents
 - Microbial seeding
 - Tilling of surface sediments (agitation)

Exhibit 1.4 (continued)

RIVERINE ROCK BOTTOM

Natural recovery monitoring

RIVERINE COBBLE-GRAVEL BOTTOM

Natural recovery monitoring

Agitation

Dredging

Sediment replacement

RIVERINE SAND BOTTOM

Natural recovery monitoring

Dredging

Sediment replacement

Agitation

RIVERINE SILT-MUD BOTTOM

Natural recovery monitoring

Dredging

Sediment replacement

LACUSTRINE ROCKY SHORE

Natural recovery monitoring

Sand blasting

Steam cleaning

Flushing (pressure and temperature variables)

Flushing with chemical remediation

Bioremediation:

Fertilizer application

Oleophilic agents

Microbial seeding

LACUSTRINE COBBLE-GRAVEL SHORE

Natural recovery monitoring

Flushing (pressure and temperature variables)

Flushing with chemical remediation

Sediment washing

Agitation

Bioremediation:

Fertilizer application

Oleophilic agents

Microbial seeding

Tilling of surface sediments (agitation)

Exhibit 1.4 (continued)

LACUSTRINE SAND SHORE

- Natural recovery monitoring
- Flushing (pressure and temperature variables)
- Sediment washing
- Agitation
- Bioremediation:
 - Fertilizer application
 - Oleophilic agents
 - Microbial seeding
- Tilling of surface sediments (agitation)
- Incineration

LACUSTRINE SILT-MUD SHORE

- Natural recovery monitoring
- Sediment removal and replacement
- Bioremediation:
 - Fertilizer application
 - Oleophilic agents
 - Microbial seeding
- Tilling of surface sediments (agitation)

LACUSTRINE ROCK BOTTOM

- Natural recovery monitoring

LACUSTRINE COBBLE-GRAVEL BOTTOM

- Natural recovery monitoring
- Agitation
- Dredging
- Sediment replacement

LACUSTRINE SAND BOTTOM

- Natural recovery monitoring
- Agitation
- Dredging
- Sediment replacement
- Capping

LACUSTRINE SILT-MUD BOTTOM

- Natural recovery monitoring
- Dredging
- Sediment replacement
- Capping

Exhibit 1.4 (continued)

II. BIOLOGICAL NATURAL RESOURCE POPULATIONS:

SHELLFISH

- Natural recovery monitoring
- Harvest alteration
- Restocking (various ages)
- Enhancement
- Artificial reefs

FISH

- Natural recovery monitoring
- Harvest alteration
- Restocking (various ages)
- Enhancement
- Artificial reefs
- Stream restoration
- Fish passageway improvement

REPTILES

- Natural recovery monitoring
- Harvest alteration
- Restocking (various ages)
- Enhancement

BIRDS

- Natural recovery monitoring
- Harvest alteration
- Restocking (various ages)
- Enhancement

MAMMALS

- Natural recovery monitoring
- Harvest alteration
- Restocking (various ages)
- Enhancement